Resurvey of Northern Abalone, *Haliotis kamtschatkana*, Populations in Southeast Queen Charlotte Islands, British Columbia, April, 2002

M. Atkins, J. Lessard, and A. Campbell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
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RESURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS IN SOUTHEAST QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA, APRIL 2002

by

M. Atkins, J. Lessard, and A. Campbell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

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ABSTRACT

Atkins, M., Lessard, J., and Campbell, A. 2004. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations in southeast Queen Charlotte Islands, British Columbia, April 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2704: 37 p.

Northern abalone, *Haliotis kamtschatkana*, have been protected by harvest closures since 1990 due to low population levels. Index site surveys have been performed since 1978 to monitor abalone populations in British Columbia (BC). In April 2002, a total of 362 abalone were found from 45 of the 68 index sites surveyed along the southeast coast of the Queen Charlotte Islands. Mean shell length (SL) was 67.0 mm; 12.4% of abalone surveyed were of historic legal size (≥100 mm SL). Abalone density for all sizes was 0.34/m^2, significantly lower than all previous survey years (except 1994). Densities of legal and of mature (≥70 mm SL) abalone were significantly lower in 2002 than all other years. Since the fishery closure in 1990, there has been no evidence of a recovery of northern abalone populations in southeast Queen Charlotte Islands.

RÉSUMÉ

Atkins, M., Lessard, J., and Campbell, A. 2004. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations in southeast Queen Charlotte Islands, British Columbia, April 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2704: 37 p.

La pêche de l'ormeau nordique, *Haliotis kamtschatkana*, de la Colombie-Britannique est complètement fermée depuis 1990 afin d'assurer la conservation de l'espèce. Des relevés à des sites indicateurs ont été effectués par Pêches et Océans Canada depuis 1978 pour surveiller le rétablissement des populations d'ormeaux. En avril 2002, 362 ormeaux ont été mesuré à 45 des 68 sites échantillonnés sur la côte sud-est des Îles de la Reine Charlotte. La longueur moyenne était 67.0 mm et 12.4% des ormeaux échantillonnés étaient de taille légale (≥100 mm de longueur). La densité totale estimée était de 0.34/m^2, une baisse significative comparée à tous les échantillonnages précédents, sauf celui de 1994. Les densités d'ormeaux légaux et mature (≥70 mm de longueur) étaient elles aussi à leurs plus bas niveaux comparativement à tous les échantillonnages précédents. Les résultats indiquent que les populations d'ormeaux nordiques ne se rétablissent pas sur la côte sud-est des Îles de la Reine Charlotte depuis la fermeture de la pêche.

INTRODUCTION

Generally occurring in patchy distributions on exposed or semi-exposed coastlines in British Columbia (BC) the northern abalone, *Haliotis kamtschatkana*, is found from Yakutat, Alaska to Baja California (McLean 1966; O'Clair and O'Clair 1998). In BC, northern abalone were harvested by First Nations as a traditional food source, were a target of recreational divers, and a commercial fishery operated between 1952 and 1990 (Campbell 2000). The biology and fishery of the northern abalone were reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992).

Northern abalone stocks have been assessed through surveys of index sites in southeast Queen Charlotte Islands (QCI) (Pacific Fishery Management Area (PFMA) 2 east) and the north central coast of BC (PFMA 5 and 6) using a standard survey design since 1978 (Breen and Adkins 1979). Much of the commercial fishery for northern abalone was conducted in these areas during 1977-90 (Harbo 1997). Results from the surveys of index sites along the central coast of BC and the Queen Charlottes showed evidence of a 75-80% decline in abalone abundance in the period of 1978-1990 (Thomas et al. 1990; Farlinger et al. 1991; Campbell 2000). The Department of Fisheries & Oceans Canada (DFO) banned the harvest of northern abalone in December of 1990 due to conservation concerns. Despite the harvest closure, their numbers remained low and in 1999 northern abalone was listed as 'threatened' by the Committee on the Status of Endangered Wildlife in Canada (Campbell 2000; Jamieson 2001).

As a result of the official listing, a National Recovery Strategy for the Northern Abalone was prepared by the DFO and the Abalone Recovery Team (Abalone Recovery Team 2002). The short-term measurable objective set out in the recovery strategy is: "[to] ensure that mean densities of adult (≥100 mm SL) northern abalone do not decline below 0.1/m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites without adult (≥100 mm SL) northern abalone does not increase to greater than 60%". In order to monitor northern abalone and evaluate recovery efforts, the surveys of index sites have continued.

This paper presents the results of the index sites survey in the southeast QCI in April 2002 (Fig. 1) and compares abalone density estimates with those measured in previous surveys (Breen and Adkins 1979; 1981; Boutillier et al. 1985; Carolsfeld et al. 1988; Thomas et al. 1990; Winther et al. 1995; Campbell et al. 2000).

METHODS

SURVEY METHODS

The Coast Guard research vessel 'CCGS W.E. Ricker' acted as a live-aboard platform for the survey crew. Two dive teams, consisting of three DFO divers each, worked from two smaller dive boats, for eight days, April 12-19, 2002.

Eight abalone surveys have been completed in southeast QCI since 1978. During the first survey in 1978, 108 sites were surveyed using the standard method described

below, but several of these sites were not re-sampled in 1984 and did not become 'index sites' (location re-sampled at each survey). Only 10 sites were surveyed in 1979, of which 7 were repeats from 1978. In 2002, most of the index sites sampled in previous surveys since 1984 were resurveyed. Index site positions were located from previous chart records, written site descriptions, photographs and GPS positions. In 1998, in addition to index sites, additional sites were randomly selected and surveyed. In this paper, when the additional sites from 1978 and 1998 were included in the analysis, the combination is referred as 'all sites'.

The sites were grouped into eight general areas: Cumshewa Inlet, Selwyn Inlet, Tanu Island, Upper Juan Perez Sound, Lower Juan Perez Sound, Skincuttle Inlet, Carpenter Bay, Kunghit Island (Fig. 1).

Abalone index sites were surveyed using the method described by Breen and Adkins (1979). Once each site was located, divers placed a $1m^2$ quadrat at the top of the abalone habitat zone and then sampled 16 quadrats within a 7m by 16m area (4 rows of 4 quadrats). The 16 quadrats were arranged in 4 transects, each 4 m apart; each of the 4 quadrats, within a transect, were 1 m apart. For each quadrat, divers recorded the dominant algal species and the number of urchins, and cleared the quadrat of all kelp, sea urchins, and sea stars to ensure all exposed abalone were easily detectable. Divers then recorded the depth and substrate type, and measured, with callipers, the shell length (SL in mm) of each exposed abalone. If no abalone were encountered in the first eight quadrats, the dive was aborted and the site count was scored as zero.

In the 1984, 1987 and 1990 surveys, divers turned boulders and rocks in search of hidden or cryptic abalone, but, in an effort to conserve time and increase sample size, only exposed abalone were recorded on the 2002 survey. Searching for cryptic abalone is time-consuming and only 15-17% more abalone are seen during a cryptic search (Cripps and Campbell 1998; Campbell and Cripps 1998). Data for cryptic abalone from 1984, 1987 and 1990 were excluded from the analyses in this paper.

ANALYTICAL METHODS

Abalone densities were expressed as the number/m^2 for several size categories: all sizes, immature (<70 mm SL), mature (≥70 mm SL), pre-recruit (92-99 mm SL), new recruit (100-106 mm SL) and legal (≥ 100 mm SL). Size at 100% maturity for northern abalone is approximately 70 mm SL (Campbell et al. 1992). Pre-recruit and new recruit sizes for northern abalone were estimated using growth curves provided by Quayle (1971) and Breen (1986). The number of abalone measured at a site occasionally did not match the number counted because some may not have been accessible or the shells were broken. For this reason, the size frequencies for each site were used to estimate the proportion of abalone within each size category. Densities for each size category (D_i) were calculated as $D_i = P_i D$, where P_i is the proportion of abalone in each category (P_i = the number per category *i* divided by the total abalone measured in the sample) and D is the density (abalone/m^2) calculated from the total abalone count from the 16 quadrats. In 1978, abalone were not measured at all sites, but the legal proportion was estimated. Therefore, 1978 density estimates for immature, mature,

pre-recruit, and new-recruit could not be calculated for 57 sites (out of 108). For all survey years, densities of immature abalone should be treated with caution due to the difficulty of detecting small individuals (<70mm SL).

All the data from all index sites surveys was recently entered in a Microsoft Access database. Some errors were corrected when preparing the data for the database; therefore estimates presented in this paper (Appendix 4,5,6), for some sites, may differ slightly from previously published estimates.

A Kolmorgorov-Smirnov two-sample test was used to test for differences in mean shell length between each of the eight general survey areas in 2002. A one-way ANOVA was used to compare mean shell length over all years; if differences were detected at the 0.05 confidence level, a post-hoc Bonferroni test was used for comparisons between years.

Previous analyses of index site surveys compared changes in densities between years for repeated sites only and several sites were ignored. This meant that each time a particular site was not surveyed because of weather conditions, or other reason, the number of sites included in the analysis decreased. In 2002, of the 68 sites surveyed, only 55 had the complete time-series for all sizes and legal density estimates, and only 24 for the other size categories where size frequencies were available. Considering the amount of effort necessary to survey each site, all sites should be included in the analysis, if possible. For this reason, the analysis in this paper was changed. The non-parametric Kruskal-Wallis test was used in order to include as many sites as possible while considering each site an independent sample. This made the comparison between years with different sample sizes possible. The Kruskal-Wallis test was used to compare densities between all years for all sizes, legal, mature, pre-recruit and new recruit abalone; if differences were detected at the 0.05 confidence level, a Mann-Whitney U was used for comparisons between years.

RESULTS

SURVEY SUMMARY

In total, 68 historic index sites were sampled for abalone density. Abalone were found at 45 (66.2%) of the 68 sites surveyed. No abalone were found at any sites surveyed in the Cumshewa Inlet area. An average of 32.3 minutes (minimum 5, maximum 78) was spent sampling each site (Appendix 1). In general the sites consisted of bedrock and/or boulders. *Macrocystis integrifolia*, *Nereocystis luetkeana*, *Pterygophora californica* and *Laminaria* spp. were the dominant kelp species (Appendix 2). Encrusting coralline algae were present at most sites.

SIZE FREQUENCY

In total, 362 abalone were measured during the survey. The mean shell length was 67.0 mm; the smallest abalone measured was 8 mm and the largest was 135 mm (Fig. 2, 3; Table 1). Excluding Cumshewa Inlet, from which no abalone were found, there were two areas (Selwyn Inlet and Lower Juan Perez Sound) from which no legal

sized abalone were found, although in both cases the total abalone counts were small (<10).

Mean shell lengths were compared between areas using the Kolmogorov-Smirnov two sample test (Table 1). Lower Juan Perez Sound had the smallest mean size (54.8 mm SL), which was significantly different ($P \leq 0.05$) from both Tanu and Kunghit Islands areas. The largest mean size (76.3 mm SL) was in Kunghit Island area and was significantly higher ($P \leq 0.05$) than the mean sizes in Tanu Island, Upper Juan Perez Sound, and Carpenter Bay.

In 2002, the mean size (67.0 mm SL) was significantly smaller ($P<0.05$) than all other survey years, except 1978 (Tables 2 and 3).

DENSITY

Of the seven areas with abalone, densities for all sizes ranged from 0.04 abalone/m^2 (Selwyn Inlet) to 0.79 abalone/m^2 (Kunghit Island) (Table 4). Density estimates by size categories and by area were very low or zero. For this reason, only 'all sizes' density estimates were compared between areas (Cumshewa Inlet area was excluded). Kunghit Island had significantly more abalone than Selwyn Inlet, Tanu Island and Skincuttle Inlet. Amongst areas with abalone present, Selwyn Inlet had the lowest density all sizes, which was significantly different from Tanu Island, Upper Juan Perez and Kunghit Island areas. Carpenter Bay had the highest density of immature (<70 mm SL) abalone with 0.35 abalone/m^2. Kunghit Island had the highest density of legal (≥100 mm SL) abalone with 0.12 abalone/m^2.

Mean densities of different abalone size groups for all surveyed sites were compared between survey years (Table 5, 6, and Appendix 3, 4, 5). Abalone densities declined significantly between 1978 and 1984 and have since fluctuated (Fig. 4). In all size classes, abalone densities were significantly higher ($P<0.05$) in 1978-79 than all subsequent years (Table 6). There were no significant differences between 1978 and 1979 except for the density of new recruits. The density of legal sized and mature abalone was significantly lower in 2002 than all previous survey years. The 2002 abalone density estimate of all sizes was significantly lower than all other years except 1994 (Table 6).

PERCENT OF SITES WITH ABALONE

The overall percentage of sites with no exposed abalone was 30.9%, and with no exposed legal-sized abalone was 75.0%, for all index sites sampled (N=68) in 2002. When comparing between areas, these values ranged from 0% to 100% for total abalone and 14% to 100% for legal abalone (Table 7). There were three areas (Cumshewa Inlet, Selwyn Inlet and Lower Juan Perez Sound) in which no legal-sized abalone were observed; this was probably due, in part, to the low number of sites sampled within each area (4, 6, and 2 sites respectively).

The 2002 survey had the highest percentage of sites with any exposed abalone (30.9%), the next closest being 1984 (15.7%). The percentage of sites with no legal abalone increased from 23.1% in 1978 to 75.0% in 2002 (Fig. 5).

DISCUSSION

While the current data analysis methods differed, the results of the statistical analysis presented here were similar to Campbell et al. (2000) (e.g., 'all sizes' densities between 1987 and 1990 were significantly different using both type of analysis). The discrepancies were probably due to the different number of sites included in the respective analysis.

The mean size of abalone surveyed significantly dropped from 76.4 mm SL in 1998 to 67.0 mm SL in 2002 (Table 2). This decrease was likely due to a greater proportion of small individuals. While there was a significant decline of 'all sizes' density from 1998 to 2002 of 39%, the legal and mature densities went down by 56% and 64%, respectively, compared to 18% for immature (Table 5). In other words, the density for large abalone decreased more rapidly than that for small individuals.

Abalone population density estimates for southeast QCI during the 2002 survey (0.34 ± 0.06 abalone/m^2) were higher than the densities observed during the most recent survey along the central coast of BC in 2001 (0.27 ± 0.04 abalone/m^2; Atkins et al. 2004) and a preliminary survey of the northwest coast of Vancouver Island (0.09 ± 0.04 abalone/m^2; Atkins and Lessard 2004).

Abalone population abundance in southeast QCI in 2002 could be reaching a critical density too low to maintain a sustainable population. The minimum density under which reproductive potential is impaired due to rarity, known as the Allee effect (Allee et al. 1949) is unknown for northern abalone. Shepherd and Partington (1995) showed that there was a critical stock density threshold (0.15-0.20 abalone/m^2) for *H. laevigata*, below which the risk of recruitment failure was high. Shepherd and Brown (1993) observed a 50% decline in the proportion of aggregating adults in *H. laevigata* when density declined from 1.8 to 0.7/m^2. They reasoned that the loss of reproductive potential was multiplied by a factor related to the ability of abalone to aggregate. In other words, the effective population size (the population contributing to the next generation) declines more rapidly than the true population size as density declines. These aggregations are believed to enhance reproductive success by increasing the chance of fertilization (Sloan and Breen 1988; Shepherd and Brown 1993; McShane 1995a, 1995b; Shepherd and Partington 1995; Babcock and Keesing 1999). Recent studies in abalone (McShane 1995a, 1995b; Shepherd and Partington 1995; Babcock and Keesing 1999) and sea urchins (Levitan et al. 1992; Levitan and Sewell 1998) have pointed to reduced fertilization success caused by dilution of gametes through reduced adult spawner densities. For *H. kamtschatkana*, Breen (1986) suggested pre-recruit (92-99 mm SL) and new-recruit (100-106 mm SL) densities of 0.55/m^2 and 0.45/m^2, respectively, as replacement requirement densities with an ongoing fishery. Campbell (1997) suggested densities 0.26/m^2 for pre-recruits and 0.14/m^2 for new-recruits would be required for the reopening of the fishery in BC; the suggested required densities for the reopening of the fishery were set arbitrarily at slightly higher than 50% of the peak densities during the late 1970s. In the 2002 survey, the densities of pre-recruit and new-recruit abalone were 0.02/m^2 and 0.02/m^2 respectively, well below both the suggested harvestable replacement density levels.

CONCLUSION

The mean density of 'legal' abalone (>100mm in SL) was only at 0.04/m^2 (Table 5; Fig.4), well below the short-term objective of maintaining densities at or above 0.1/m^2 (Abalone Recovery Team 2002). The percentage of sites with no legal sized abalone, 75% in 2002 (Table 7; Fig. 5), was also above the short-term recovery target of 60%. The number of sites without any or legal sized abalone should be treated with caution. The number of secondary units (quadrats) sampled could potentially change the relative quantity of zero sites (Campbell et al. 2000). With the current sampling design, the dive is aborted after the eight quadrats if no abalone are encountered and the site count is scored as zero. The 'Breen' survey method has provided a valuable time series of general population trends of mature emergent northern abalone at index sites in large remote areas of BC. The method has had few changes since 1978 and has made survey comparisons between year and location possible. However, abalone densities have decreased and the probability of encountering an abalone in 8 quadrats is lower than it was in the late 1970s. We recommend that the 'Breen' survey method continue to be used, but for repeated index sites, all 16 quadrats should be completed even when no abalone are found after the 8th quadrat.

There has been no evidence of abalone populations rebuilding in the southeast QCI in the 14 years since abalone were protected by harvest closures which started in late 1990. The densities of every size group, except new-recruit, have significantly decreased from the 1998 estimates. The proportionally larger decrease in densities of mature and legal compared to immature abalone density suggests that the main factor in the overall decline was probably not low recruitment, but poaching. Although other factors, e.g. natural predation, have played a role, low recruitment levels and continued harvest despite the fisheries closures probably have had predominant and widespread effects and are considered to be the most significant threats to northern abalone recovery (Abalone Recovery Team 2002). Poachers target larger individuals, which have the highest reproductive potential, compounding the impact of their removal on the surrounding population. The level of poaching is difficult to assess. Abalone are valued between $45-100/kg fresh/frozen to $2600/kg for dried meat, making them a very profitable commodity (Campbell 2000; Jubinville 2000). Poaching does come with risk; several people have been sentenced to over $170 000 in fines and equipment forfeitures (Jubinville 2000). In addition to enhancing public education and awareness, active enforcement must be increased to reduce the impact poaching has on the future of northern abalone populations in BC.

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REFERENCES

Abalone Recovery Team. 2002. National Recovery Strategy for the Northern Abalone (*Haliotis kamtschatkana*) in Canada. 22 pp. http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/abalone/documents/AbaloneRecovStrategy_e.htm

Allee, W.C., Emerson, A.E., Park, O., Park, T., and Schmidt, K.P. 1949. Principles of Animal Ecology. Saunders, Philadelphia. 837 p.

Atkins, M., and Lessard, J. 2004. Survey of northern abalone, *Haliotis kamtschatkana*, populations along north-west Vancouver Island, British Columbia, May 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2690: 12 p.

Atkins, M., Lessard, J., and Campbell, A. 2004 (in press). Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, April 2001. Can. Manuscr. Rep. Fish. Aquat. Sci.

Babcock, R., and Keesing, J. 1999. Fertilization biology of the abalone *Haliotis laevigata*: laboratory and field studies. Can. J. Fish. Aquat. Sci. 56: 1668-1678.

Boutillier, J.A., Carolsfeld, W., Breen, P.A., Farlinger, S., and Bates, K. 1985. Abalone resurvey in the southeast Queen Charlotte Islands, July 1984. Can. Manuscr. Rep. Fish. Aquat. Sci. 1818: 87 p.

Breen, P.A. 1986. Management of the British Columbia fishery for northern abalone (*Haliotis kamtschatkana*). Can. Spec. Publ. Fish. Aquat. Sci. 92: 300-312.

Breen, P.A. and Adkins, B.E. 1979. A survey of abalone populations on the east coast of the Queen Charlotte Islands, August 1978. Fish. Mar. Serv. Manuscr. Rep. 1490: 125 p.

Breen, P.A. and Adkins, B.E. 1981. Abalone surveys and tagging conducted during 1979. Can. Manuscr. Rep. Fish. Aquat. Sci. 1623: 88 p.

Campbell, A. 1997. Possible criteria for reopening the northern abalone (*Haliotis kamtschatkana*) fishery in British Columbia. DFO Can. Stock Assess. Sec. Res. Doc. 1997/64: 47 p.

Campbell, A. 2000. Review of northern abalone, *Haliotis kamtschatkana*, stock status in British Columbia. *In* Workshop on Rebuilding Abalone Stocks in British Columbia. *Edited by* A. Campbell. Can. Spec. Publ. Fish. Aquat. Sci. 130. pp. 41-50.

Campbell, A., Brouwer, D., Rogers, J., and Miller, D.C. 2000. Abalone resurvey in south east Queen Charlotte Islands, 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2528: 30 p.

Campbell, A., and Cripps, K. 1998. Survey of abalone populations at Stryker Island, Tribal Group and Simonds Group, Central Coast of British Columbia, May 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2451: 21 p.

Campbell, A., Manley, I., and Carolsfeld, W. 1992. Size at maturity and fecundity of the abalone, *Haliotis kamtschatkana*, in northern British Columbia. Can Manuscr. Rep. Fish. Aquat. Sci. 2169: 47-65.

Carolsfeld, W., Farlinger, S., Kingzett, B.C., Sloan, N.A., and Thomas, G. 1988. Abalone resurvey in the southeast Queen Charlotte Islands, June 1987. Can. Manuscr. Rep. Fish. Aquat. Sci. 1966: 90 p.

Cripps, K., and Campbell, A. 1998. Survey of abalone populations at Dallain Point and Higgins Pass, central coast of British Columbia, 1995-96. Can Manuscr. Rep. Fish. Aquat. Sci. 2445: 31 p.

Farlinger, S., and Campbell, A. 1992. Fisheries management and biology of northern abalone, *Haliotis kamtschatkana*, in the northeast Pacific. pp. 395-406 *In* Shepherd, S.A., Tegner, M.J., Guzmán del Próo, S.A. (eds), Abalone of the World - Biology, Fisheries and Culture. Fishing News Books, Oxford.

Farlinger, S., Thomas, G.A., Winther, I., and Carolsfeld, W. 1991. Abalone resurvey in the Estevan Group and Aristazabal Island, June 1989. Can. Manuscr. Rep. Fish. Aquat. Sci. 2104: 39 p.

Harbo, R. 1997. Abalone dive fishery (closed). Can. Manuscr. Rep. Fish. Aquat. Sci. 2369: 86-92.

Jamieson, G.S. 2001. Review of status of northern abalone, *Haliotis kamstchatkana*, in Canada. Canadian Field-Naturalist 115: 555-563.

Jubinville, B. 2000. Enforcing the fishery closure for northern (pinto) abalone (*Haliotis kamtschatkana*) in British Columbia [Abstract]. *In* Workshop on Rebuilding Abalone Stocks in British Columbia. *Edited by* Campbell, A. Can. Spec. Publ. Fish. Aquat. Sci. 130. pp. 52.

Levitan, D.R., and Sewell, M.A. 1998. Fertilization success in free-spawning marine invertebrates: review of the evidence and fisheries implications. Can. Spec. Publ. Fish. Aquat. Sci. 125: 159-164.

Levitan, D.R., Sewell, M.A., and Chia, F.-S. 1992. How distribution and abundance influence fertilization success in the sea urchin *Strongylocentrotus franciscanus*. Ecology 73: 248-254.

McLean, J. 1966. West American prosobranch gastropoda: Superfamilies Patellacae, Pleurotomariacea, and Fissurellacea. Ph.D. Thesis, Stanford University. 255 p.

McShane, P.E. 1995a. Estimating the abundance of abalone: the importance of patch size. Marine and Freshwater Research 46: 657-662.

McShane, P.E. 1995b. Recruitment variation in abalone: its importance to fisheries management. Aust. J. Mar. Freshwat. Res. 46: 555-570.

O'Clair, R.M., and O'Clair, C.E. 1998. Southeast Alaska's Rock Shores. Animals. Plant Press, Auke Bay, Alaska. 564 p.

Quayle, D.B. 1971. Growth, morphometry and breeding in the British Columbia abalone, *Haliotis Kamtschatkana*. Fish. Res. Bd Can. Tech. Rep. Ser. 279: 84 p.

Shepherd, S.A., and Brown, L.D. 1993. What is an abalone stock: implications for the role of refugia in conservation. Can. J. Fish. Aquat. Sci. 50: 2001-2009.

Shepherd, S.A., and Partington, D. 1995. Studies on southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. Marine and Freshwater Research 46: 669-680.

Sloan, N.A., and Breen, P.A. 1988. Northern abalone, *Haliotis kamtschatkana*, in British Columbia: fisheries and synopsis of life history information. Can. Spec. Public. Fish. Aquat. Sci. 103: 46 p.

Thomas, G., Farlinger, S., and Carolsfeld, W. 1990. Abalone resurvey in the southeast Queen Charlotte Islands in 1990. Can. Manuscr. Rep. Fish. Aquat. Sci. 2099: 66-82.

Winther, I., Campbell, A., Thomas, G.A., Adkins, B.E. and Clapp, B.G. 1995. Abalone resurvey in the southeast Queen Charlotte Islands, 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2273: 46 p.

Table 1. Summary of exposed abalone shell length data from index sites surveyed in southeast QCI, 2002 by area. SE = standard error of the mean. Means followed by the same letter were significantly different (P<0.05) from each other, using a Kolmogorov-Smirnov two sample test.

	Shell Length (mm)					Total	Percent Legal
Area	**Mean**	**Median**	**SE**	**Minimum**	**Maximum**	**Count**	**≥100 mm SL**
Cumshewa Inlet	n/a	n/a	n/a	n/a	n/a	0	0.0
Selwyn Inlet	62.8	65	4.4	51	70	4	0.0
Tanu Island	65.6[a,c]	65	3.1	25	117	43	4.7
Upper Juan Perez	59.9[d]	55	3.3	14	128	93	15.1
Lower Juan Perez	54.8[a,b]	56.5	4.7	39	68	6	0.0
Skincuttle Inlet	71.1	71	4.4	26	123	34	23.5
Carpenter Bay	65.5[e]	67	2.7	8	121	94	9.6
Kunghit Island	76.3[b,c,d,e]	80	2.3	20	135	88	14.8
Total	67.0	68	1.4	8	135	362	12.4

Table 2. Mean abalone shell length (SL), standard error of the mean (SE) and number of exposed abalone measured (N) for 'all sites' sampled in southeast QCI by year.

	Year							
	1978	1979	1984	1987	1990	1994	1998	2002
Mean SL (mm)	69.5	80.2	74.1	81.3	76.8	77.7	76.4	67.0
SE	0.6	1.3	1.1	1.1	1.1	1.0	0.8	1.4
N	2102	328	583	718	581	725	1029	362

Table 3. ANOVA results comparing the mean size of abalone, from all sites, between years. Numbers represent P-values from the multiple comparison Bonferroni test. Bold numbers indicate significant difference (α = 0.05).

	Year						
Year	1978	1979	1984	1987	1990	1994	1998
1979	**0.005**						
1984	**0.000**	**0.023**					
1987	**0.000**	1.000	**0.000**				
1990	**0.000**	1.000	1.000	0.056			
1994	**0.000**	1.000	0.401	0.248	1.000		
1998	**0.000**	0.646	1.000	**0.003**	1.000	1.000	
2002	1.000	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**

Table 4. Mean exposed abalone density estimates (number/m^2) of abalone by size category and by area, southeast QCI 2002. The values in brackets are the standard errors of the mean. All sizes means followed by the same letter were significantly different ($P<0.05$) from each other, using a non-parametric Kruskal-Wallis test (Cumshewa Inlet area was excluded).

	Cumshewa Inlet	Selwyn Inlet	Tanu Island	U Juan Perez	L Juan Perez	Skincuttle Inlet	Carpenter Bay	Kunghit Island	All sites
No. of Sites	4	6	8	18	2	13	10	7	68
All sizes	0.00	0.04[abc]	0.34[b]	0.32[bd]	0.19	0.16[e]	0.61	0.79[ade]	0.34
		(0.02)	(0.10)	(0.09)	(0.19)	(0.05)	(0.24)	(0.24)	(0.06)
Immature (<70 mm SL)	0.00	0.03	0.20	0.21	0.19	0.08	0.35	0.29	0.18
		(0.02)	(0.07)	(0.08)	(0.19)	(0.02)	(0.21)	(0.07)	(0.04)
Mature (≥70 mm SL)	0.00	0.01	0.14	0.11	0.00	0.09	0.26	0.50	0.15
		(0.01)	(0.05)	(0.03)		(0.04)	(0.09)	(0.20)	(0.03)
Pre-Recruit (92-99 mm SL)	0.00	0.00	0.01	0.01	0.00	0.00	0.06	0.09	0.02
			(0.01)	(0.01)			(0.03)	(0.04)	(0.01)
New Recruit (100-106 mm)	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.09	0.02
				(0.01)		(0.01)	(0.01)	(0.04)	(0.01)
Legal (≥100 mm SL)	0.00	0.00	0.02	0.05	0.00	0.04	0.06	0.12	0.04
			(0.02)	(0.02)		(0.02)	(0.04)	(0.04)	(0.01)

Table 5. Mean exposed abalone density estimates (number/m^2) by year and by size category, from 'all sites' southeast QCI 2002. The values in brackets are the standard errors of the mean. * only 51 sites used for density estimates of immature, mature, pre-recruit and new-recruit.

Abalone Size	Year							
	1978	1979	1984	1987	1990	1994	1998	2002
Number of sites sampled	108*	10	70	70	69	70	115	68
Number of quadrats sampled	1659	152	1044	1091	1144	2492	1840	920
Number of abalone counted	3749	369	588	724	581	747	1041	366
All sizes	2.22	2.34	0.53	0.65	0.46	0.30	0.56	0.34
	(0.24)	(0.52)	(0.06)	(0.08)	(0.06)	(0.04)	(0.05)	(0.06)
Immature (<70 mm SL)	1.40	0.58	0.22	0.24	0.20	0.12	0.22	0.18
	(0.27)	(0.22)	(0.05)	(0.06)	(0.03)	(0.02)	(0.03)	(0.04)
Mature (≥70 mm SL)	1.25	1.53	0.30	0.40	0.27	0.18	0.34	0.15
	(0.24)	(0.41)	(0.05)	(0.06)	(0.05)	(0.03)	(0.04)	(0.03)
Pre - Recruit (92-99 mm SL)	0.23	0.29	0.06	0.06	0.05	0.03	0.05	0.02
	(0.05)	(0.08)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
New Recruit (100-106 mm SL)	0.11	0.27	0.03	0.06	0.04	0.02	0.04	0.02
	(0.02)	(0.06)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Legal (≥100 mm SL)	0.36	0.49	0.09	0.19	0.10	0.06	0.11	0.04
	(0.05)	(0.18)	(0.02)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)

Table 6. Mann-Whitney U test probabilities comparing mean densities from 'all sites' between years, by size category. P-values in bold indicate significant difference (α = 0.05).

	Year						
Year	1978	1979	1984	1987	1990	1994	1998
All sizes							
1979	0.394						
1984	**0.000**	**0.000**					
1987	**0.000**	**0.000**	0.140				
1990	**0.000**	**0.000**	0.631	**0.017**			
1994	**0.000**	**0.000**	**0.046**	**0.000**	0.092		
1998	**0.000**	**0.000**	0.348	0.307	0.057	**0.000**	
2002	**0.000**	**0.000**	**0.009**	**0.000**	**0.023**	0.384	**0.000**
Immature (<70 mm SL)							
1979	0.329						
1984	**0.000**	**0.029**					
1987	**0.000**	**0.032**	0.647				
1990	**0.000**	**0.026**	0.816	0.773			
1994	**0.000**	**0.005**	0.379	0.122	0.235		
1998	**0.000**	**0.041**	0.149	0.365	0.240	**0.007**	
2002	**0.000**	**0.010**	0.583	0.302	0.458	0.796	**0.046**
Mature (≥70 mm SL)							
1979	0.415						
1984	**0.000**	**0.002**					
1987	**0.000**	**0.006**	0.054				
1990	**0.000**	**0.002**	0.923	**0.023**			
1994	**0.000**	**0.002**	0.787	**0.002**	0.578		
1998	**0.000**	**0.003**	0.165	0.312	0.131	**0.020**	
2002	**0.000**	**0.000**	**0.041**	**0.000**	**0.022**	**0.034**	**0.000**
Pre-recruit (92-99 mm SL)							
1979	0.203						
1984	**0.000**	**0.001**					
1987	**0.000**	**0.001**	0.624				
1990	**0.000**	**0.000**	0.077	0.197			
1994	**0.000**	**0.000**	0.150	0.390	0.431		
1998	**0.000**	**0.000**	0.669	0.897	0.099	0.212	
2002	**0.000**	**0.000**	**0.003**	**0.014**	0.269	**0.044**	**0.003**
New Recruit (100-106 mm SL)							
1979	**0.009**						
1984	**0.000**	**0.000**					
1987	**0.041**	**0.000**	0.065				
1990	**0.001**	**0.000**	0.664	0.167			
1994	**0.000**	**0.000**	0.927	**0.032**	0.681		
1998	**0.000**	**0.000**	0.802	0.077	0.857	0.783	
2002	**0.000**	**0.000**	0.106	**0.001**	0.055	0.080	0.051
Legal (≥100mm SL)							
1979	0.353						
1984	**0.000**	**0.001**					
1987	**0.012**	**0.027**	**0.031**				
1990	**0.000**	**0.001**	0.739	0.062			
1994	**0.000**	**0.000**	0.784	**0.010**	0.499		
1998	**0.000**	**0.001**	0.840	**0.011**	0.575	0.996	
2002	**0.000**	**0.000**	**0.010**	**0.000**	**0.004**	**0.010**	**0.012**

Table 7. Percent of sites where there were no exposed abalone, or no legal (≥100 mm SL) exposed abalone, at index sites southeast QCI, 2002.

Area	% of zero site		Number of sites
	Total	Legal	
Cumshewa Inlet	100.0	100.0	4
Selwyn Inlet	50.0	100.0	6
Tanu Island	25.0	87.5	8
Upper Juan Perez	22.2	72.2	18
Lower Juan Perez	50.0	100.0	2
Skincuttle Inlet	38.5	76.9	13
Carpenter Bay	40.0	80.0	10
Kunghit Island	0.0	14.3	7
All areas	30.9	75.0	68

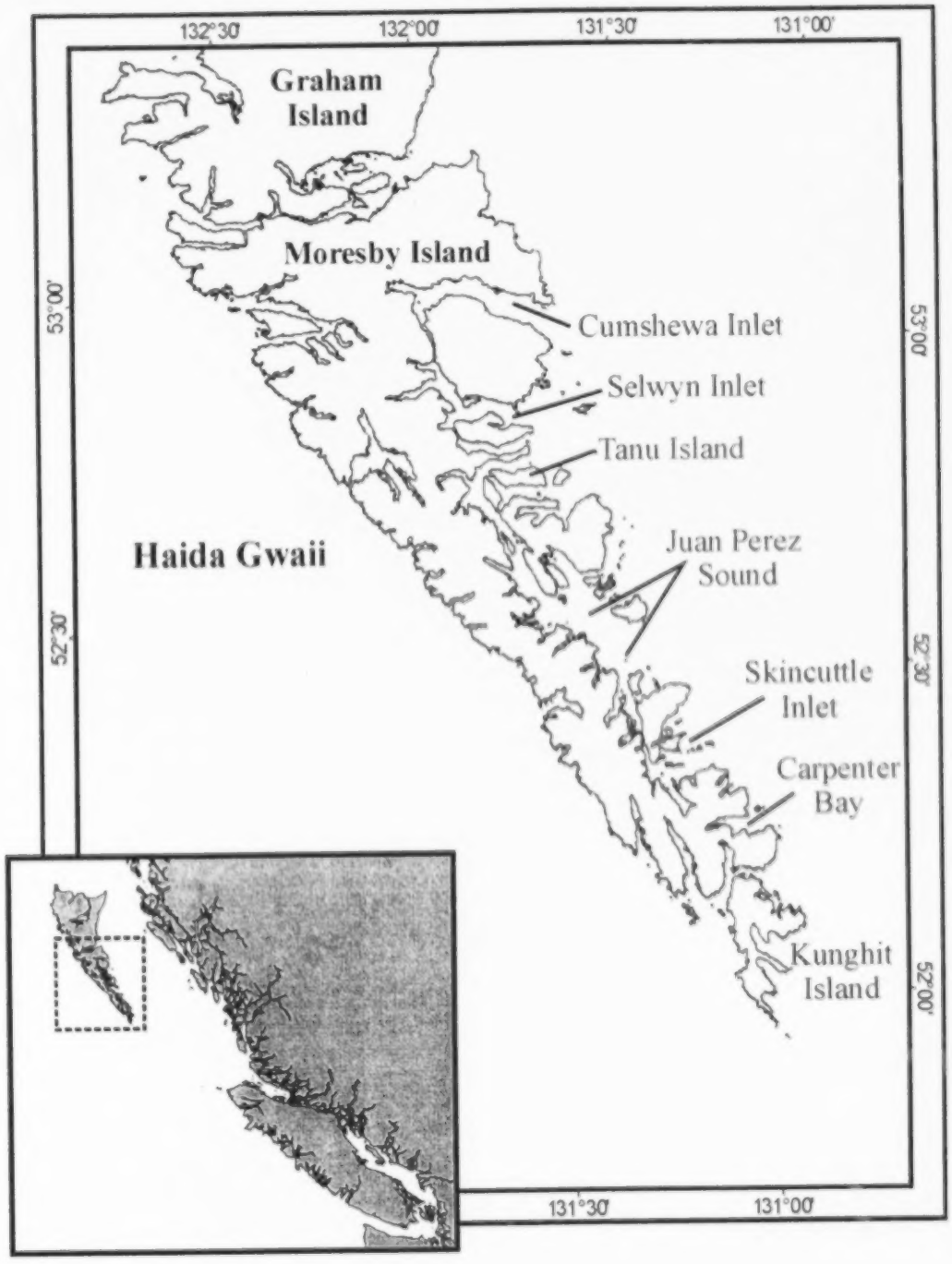

Figure 1. Map of areas surveyed in southeast QCI.

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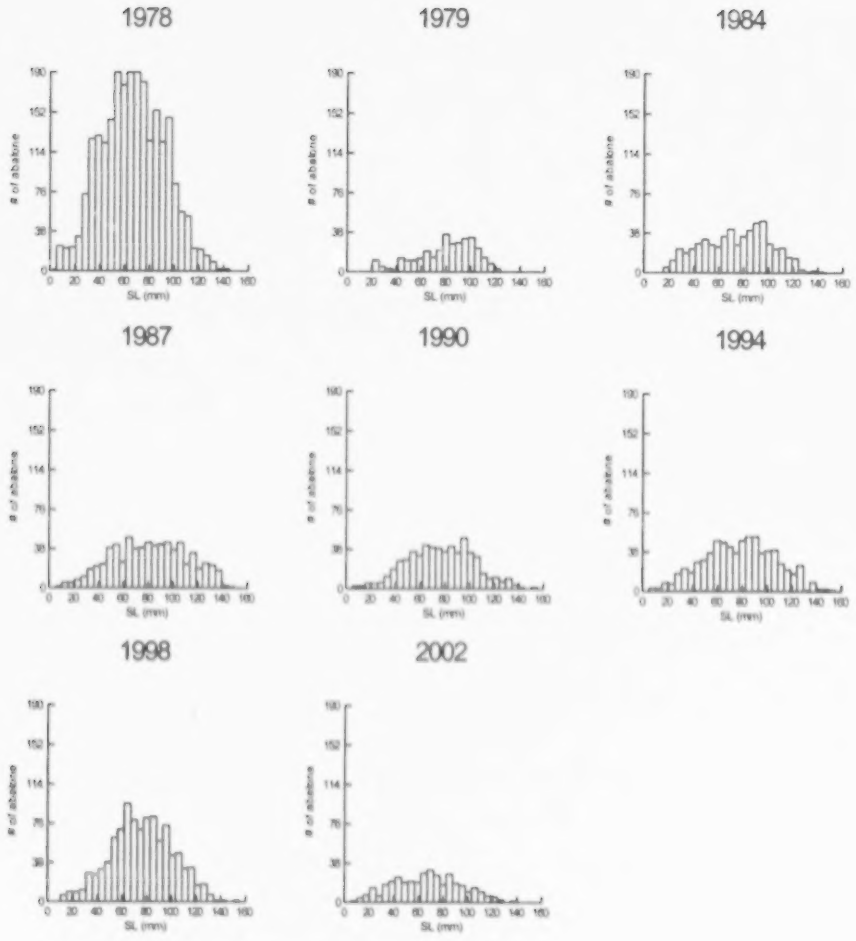

Figure 2. Size frequency of exposed abalone shell lengths (mm) measured from 'all sites' for all survey years.

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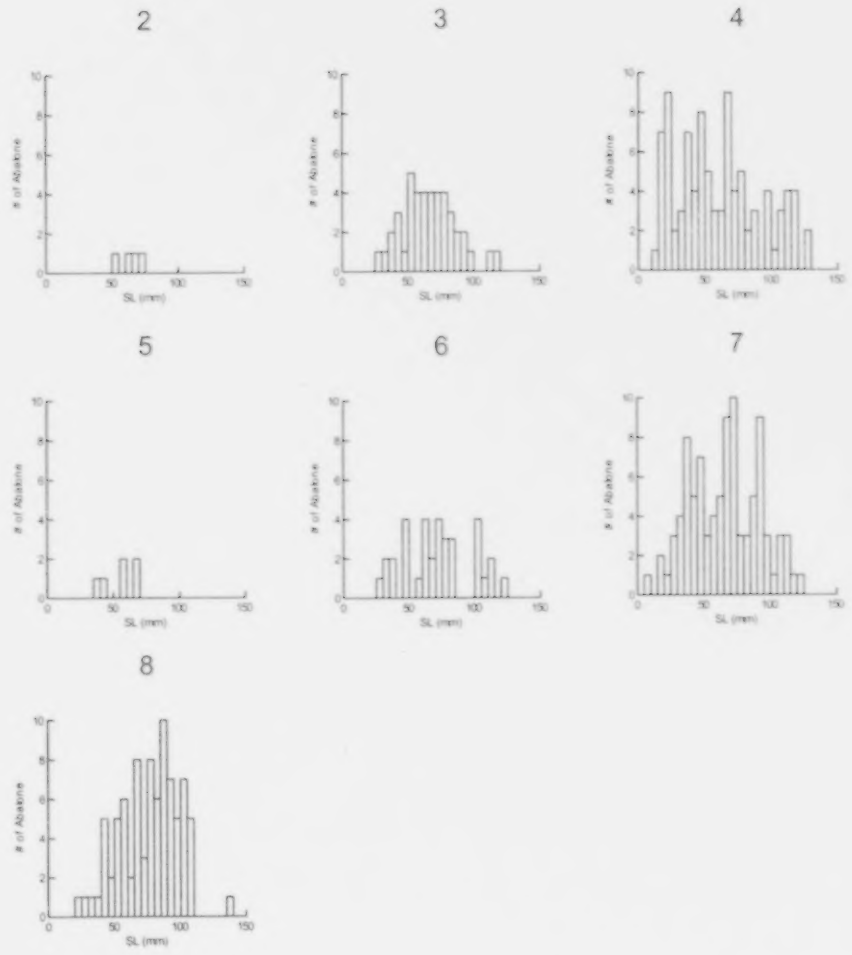

Figure 3. Size frequency of exposed abalone from each survey area in southeast QCI, April 2002. 2 = Selwyn Inlet; 3 = Tanu Island; 4 = Upper Juan Perez Sound; 5 = Lower Juan Perez Sound; 6 = Skincuttle Inlet; 7 = Carpenter Bay; 8 = Kunghit Island. See Table 1 for details.

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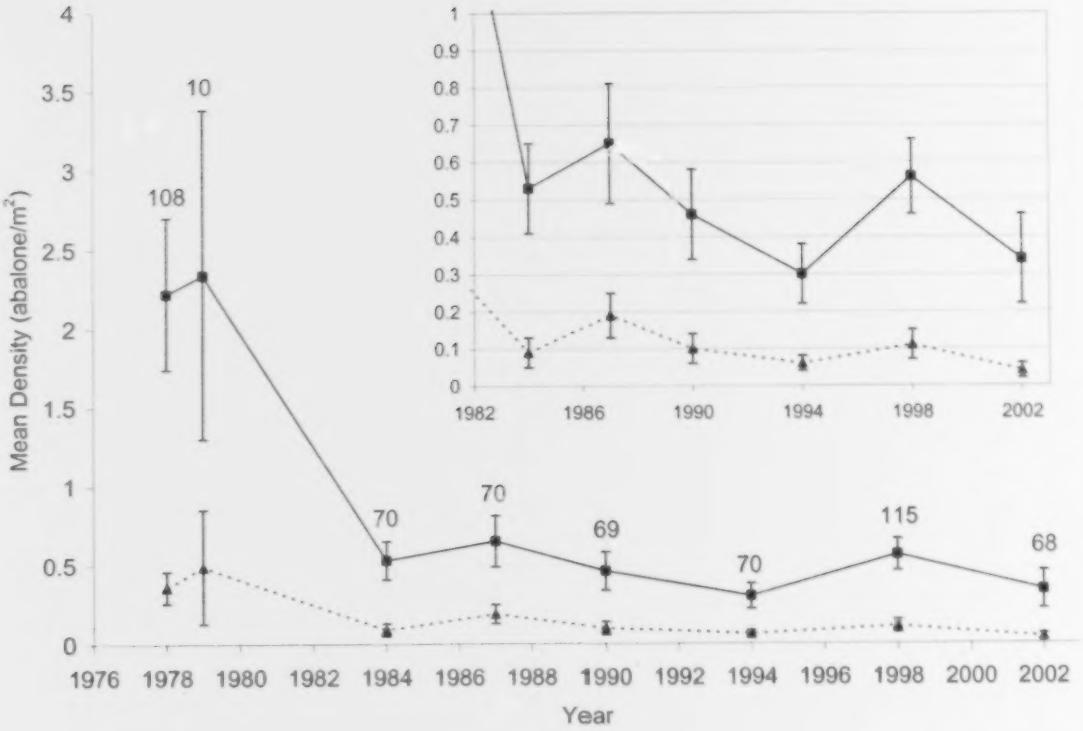

Figure 4. Mean density of 'all sizes' abalone (solid line) and 'legal' abalone (dashed line) from all surveys. All sites surveyed are included. Error bars represent 2 SE. Numbers are sample sizes. Inset graph displays greater resolution of densities for survey years after 1982.

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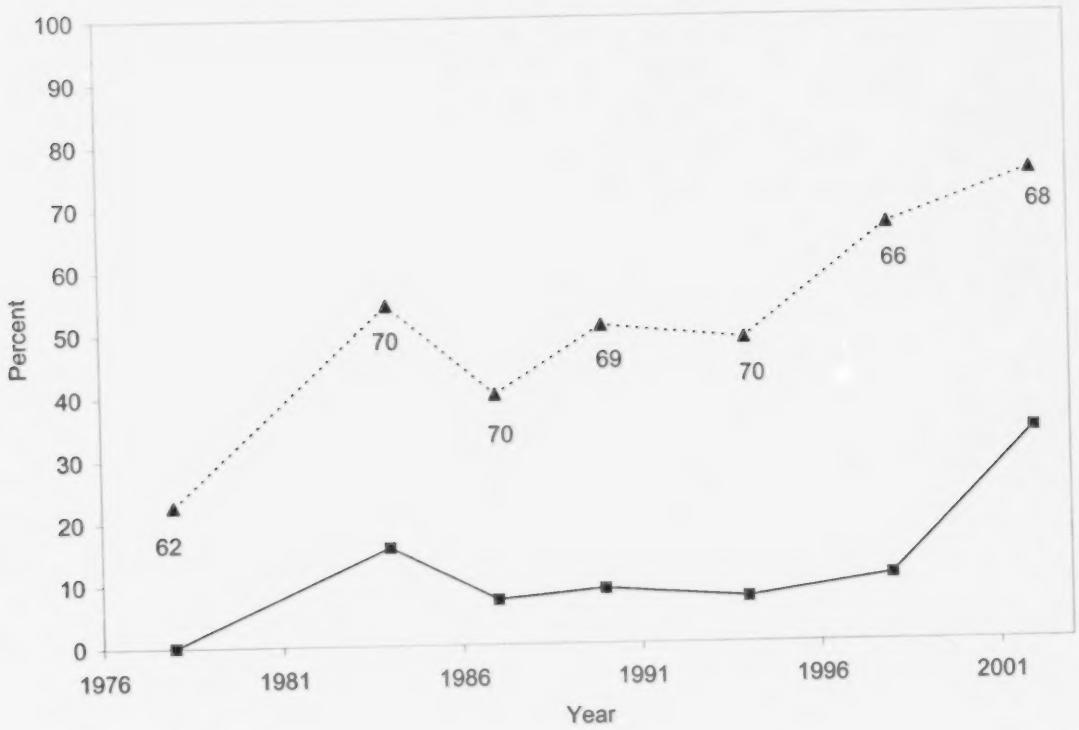

Figure 5. Percent of 'index sites' with no abalone of any size (solid line) or no 'legal' sized abalone (≥100 mm SL) (dashed line) from surveys in southeast QCI, 1978-2002 (excluding 1979 due to small sample size). Numbers are sample sizes.

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Appendix 1. Abalone dive survey summary, by site, southeast QCI, April 2002.

Site	Date	Dive Time			Depth		Number of Quadrats	Total number Of abalone	Density (abalone/m^2)
		Start	Finish	Minutes	Min	Max			
Cumshewa Inlet									
75	Apr-12	15:40	15:45	5	2	2	8	0	0.00
76	Apr-12	14:54	15:34	40	0	3	16	0	0.00
77	Apr-12	14:50	15:20	30	2	3	8	0	0.00
78	Apr-12	16:25	16:42	17	3	3	8	0	0.00
Selwyn Inlet									
65	Apr-19	11:00	11:27	27	0	3	8	0	0.00
66	Apr-19	9:40	10:05	25	-2	-1	8	0	0.00
67	Apr-19	8:53	9:22	29	-1	2	16	1	0.06
68	Apr-19	9:44	10:10	26	0	4	16	2	0.13
69	Apr-19	8:51	9:21	30	4	6	16	1	0.06
70	Apr-19	11:43	11:57	14	2	4	8	0	0.00
Tanu Island									
59	Apr-18	12:30	13:25	55	0	4	16	10	0.63
60	Apr-18	10:49	11:26	37	-1	1	16	13	0.81
61	Apr-18	13:34	14:00	26	0	3	16	4	0.25
62	Apr-18	10:03	10:23	20	-1	0	8	0	0.00
63	Apr-18	10:34	11:16	42	0	1	16	6	0.38
64	Apr-18	11:58	12:34	36	1	2	16	5	0.31
73	Apr-18	12:55	13:06	11	0	1	8	0	0.00
74	Apr-18	14:22	14:53	31	4	6	16	5	0.31
Upper Juan Perez Sound									
36	Apr-16	9:54	10:16	22	4	9	8	0	0.00
37	Apr-16	10:10	10:40	30	0	3	16	14	0.88
38	Apr-16	12:05	12:32	27	0	3	16	4	0.25
39	Apr-16	12:05	12:41	36	1	3	16	6	0.38
40	Apr-16	13:59	14:19	20	0	3	8	0	0.00
41	Apr-16	14:00	14:40	40	0	2	16	3	0.19
44	Apr-16	15:26	16:15	49	0	3	16	2	0.13
45	Apr-16	15:30	15:48	18	0	2	8	0	0.00
46	Apr-17	9:10	10:28	78	-1	4	16	24	1.50
48	Apr-17	13:59	14:51	52	0	1	16	4	0.25
49	Apr-17	14:06	14:46	40	-1	1	16	4	0.25
50	Apr-17	12:20	13:15	55	0	2	16	4	0.25
51	Apr-17	11:05	11:39	34	0	3	16	7	0.44
53	Apr-17	12:02	12:18	16	3	6	8	0	0.00
55	Apr-16	9:16	10:14	58	0	3	16	5	0.31
56	Apr-16	11:02	11:33	31	2	4	16	6	0.38
57	Apr-18	8:40	9:08	28	-1	0	16	1	0.06
58	Apr-18	8:48	9:23	35	-1	3	16	9	0.56
Lower Juan Perez Sound									
42	Apr-16	9:00	9:23	23	0	6	16	6	0.38
43	Apr-16	9:00	9:16	16	2	5	8	0	0.00

Appendix 1 (cont'd)

Site	Date	Dive Time			Depth		Number of Quadrats	Total number Of abalone	Density (abalone/m^2)
		Start	Finish	Minutes	Min	Max			
Skincuttle Inlet									
22	Apr-13	15:55	16:50	55	-1	4	16	1	0.06
23	Apr-13	17:06	17:36	30	0	0	16	3	0.19
24	Apr-13	17:04	17:20	16	-1	1	8	0	0.00
26	Apr-13	15:22	16:23	61	-1	2	16	5	0.31
27	Apr-13	15:19	15:38	19	3	4	8	0	0.00
28	Apr-13	14:19	14:42	23	0	5	8	0	0.00
29	Apr-13	13:20	14:00	40	0	4	16	4	0.25
30	Apr-13	13:20	13:43	23	1	4	16	4	0.25
31	Apr-13	11:32	12:10	38	1	2	16	5	0.31
32	Apr-13	9:25	10:04	39	4	7	16	2	0.13
33	Apr-13	11:20	11:30	10	2	3	16	10	0.63
34	Apr-13	11:39	12:00	21	0	2	8	0	0.00
35	Apr-13	9:26	9:56	30	0	1	8	0	0.00
Carpenter Bay									
10	Apr-14	14:17	14:35	18	1	3	8	0	0.00
11	Apr-14	15:01	15:27	26	0	3	16	17	1.06
12	Apr-14	12:39	12:56	17	3	4	16	10	0.63
14	Apr-14	14:00	15:10	70	-1	3	16	6	0.38
15	Apr-14	11:40	12:38	58	1	1	16	18	1.13
17	Apr-14	11:20	11:34	14	2	4	8	0	0.00
18	Apr-14	10:12	10:35	23	2	5	16	8	0.50
19	Apr-14	10:45	11:15	30	1	4	16	0	0.00
20	Apr-14	9:18	10:05	47	0	6	16	35	2.19
21	Apr-14	9:15	9:30	15	5	6	8	0	0.00
Kunghit Island									
1	Apr-15	8:30	9:07	37	1	2	16	32	2.00
2	Apr-15	9:35	10:12	37	0	2	16	12	0.75
3	Apr-15	12:32	13:17	45	0	1	16	19	1.19
4	Apr-15	11:22	11:57	35	1	5	16	9	0.56
7	Apr-15	9:20	10:00	40	0	3	16	8	0.50
71	Apr-15	14:26	15:00	34	0	1	16	6	0.38
79	Apr-15	10:30	11:05	35	1	3	16	2	0.13

Appendix 2. Description of abalone index sites surveyed in southeast QCI, April 2002. The most common substrates are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 6 = pea gravel, 7 = sand, 8 = shell. Algae are listed by growth characteristics for the most common species (Sp 1) and second most common (Sp 2) with percentage cover (%) for each, where AC = articulated corallines, AG = *Agarum* sp, AL = *Alaria* sp, BH = brown filamentous, CO = *Costaria costata*, CY = *Cymathere triplicata*, DE = *Desmarestia* sp, EG = *Egregia menziesii*, GH = green filamentous, IR = *Iridaea* sp (*Maziella* sp), LA = *Laminaria* sp., MA = *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PH = *Phyllospadix* sp, PT = *Pterygophora californica*, RF = red foliose, RH = red filamentous, UL = *Ulva* sp.

	Substrate			Slope	Canopy				Understory				Turf				Encrusting
Site	1	2	3	%	Sp1	%	Sp2	%	Sp1	%	Sp2	%	Sp1	%	Sp2	%	%
Cumshewa Inlet																	
75	6	5		0	MA	5			PT	5							
76	3	4	2	13	MA	90			LA	40	AG	40	AC	50			80
77	3	4	5	4	MA	10			PT	15			DE	40	LA	30	
78	3	7		4	MA	10			PT	10			LA	65	DE	35	
Selwyn Inlet																	
65	1	3	2	34	NT	10			CO	2			RH	20	PH	5	90
66	3	4	5	11	MA	30	PT	5	CO	5	EG	10	AC	10			70
67	1	2		21	NT	30			LA	50	CO	5	PH	70	AC	40	100
68	1	2	3	23					CO	5	AL	5					90
69	3	8	5	13					LA	85	NT	5					90
70	2	3	1	23	NT	10			CO	20	AL	20	AC	20			10
Tanu Island																	
59	2	1	3	27					LA	20	DE	30	AC	50			70
60	3	4	5	13	MA	100			CY	90	LA	50	AC	5			75
61	2	3	4	23					DE	10	CO	5					10
62	4	5	3	4	MA	10			PT	20	CO	50	AC	80			70
63	3	2	4	8					LA	30	NT	10	UL	10	GH	10	50
64	1	2	3	10	MA	20			LA	10	DE	5	AC	5			50
73	4	5		8	MA	80			CY	70	LA	70	AC	10			70
74	4	7	5	13	MA	40			AG	100							
Upper Juan Perez Sound																	
36	2			65	NT	20			DE	20			AC	10			90
37	2	1		19	NT	15			LA	25	PT	25	AC	20			100
38	2	3	8	19					PT	2	LA	3	AC	30			80
39	2	3		11	PT	70							AC	20			80
40	2	6		30	MA	10							AC	5			60
41	1	3	4	17	MA	5			AG	10			AC	50			70
44	1	3	4	21	NT	10			EG	10	PT	10	AC	2			80
45	2			30	MA	5			PH	5			AC	5			90
46	2	3		30					PT	40	AL	20	AC	20			50
48	2	1	4	8	NT	20	MA	10	LA	20	CO	5	RF	5			40
49	2	4	5	10					LA	25	CO	10	AC	2	UL	2	75
50	3	4	5	15	MA	40			CY	30	UL	30	AC	50			80
51	2	3	4	17					CY	30	AG	10	BH	75			80
53	1	2		46	NT	5			DE	5							80
55	2			15	NT	50			DE	40	PT	30	AC	10	PH	30	70
56	2	3		17	NT	10			DE	10			AC	10			90
57	2	3		10	NT	5			LA	40	CO	20	AC	20			60
58	1	2	3	23					LA	20	NT	20	AC	30			90

Appendix 2 (cont'd)

	Substrate			Slope	Canopy				Understory				Turf				Encrusting
Site	1	2	3	%	Sp1	%	Sp2	%	Sp1	%	Sp2	%	Sp1	%	Sp2	%	%
Lower Juan Perez Sound																	
42	1	2		32					PT	5			AC	1			90
43	2			27	NT	10			PT	25			AC	20			60
Skincuttle Inlet																	
22	2	1		29					CO	5	PT	5	AC	10			40
23	3	1	4	6	MA	20			LA	50	CO	30	AC	30	NT	5	50
24	2			23													40
26	3	4	8	19	MA	5			LA	1			AC	10			75
27	5	3	6	11	MA	50			AG	90			IR	5			30
28	2			61													65
29	2			27					CO	10	DE	10	AC	5			5
30	2			15									AC	5			80
31	1	2	4	19	MA	30			NT	10	CY	10	AC	50			100
32	2			21	MA	100			NT	70	PT	30	LA	90	RF	10	100
33	3			8					PT	5							95
34	2	3		27	NT	100			LA	80	DE	20	AL	60	PT	40	70
35	3	2	4	15	MA	20			CY	50	LA	20	AC	5			5
Carpenter Bay																	
10	2	8		19	MA	5			LA	5			AC	5			20
11	2	3	7	17													30
12	3	5	7	6	MA	10							DE	10			25
14	1	2		27					PT	5	LA	5	AC	5			5
15	1			2					PT	5			AC	20			100
17	3	7	2	27									AC	10			20
18	3			13													50
19	1	2	3	15					CO	3	DE	3	AC	5			
20	2	8	3	34													80
21	2	3	4	11									AC	10			70
Kunghit Island																	
1	2	3	7	8	MA	10			AL	10			AC	15			90
2	3			10	MA	10			AL	5			CO	20			95
3	3	4	2	8	MA	25			PT	25	NT	10	DE	10	CO	10	60
4	2	3	4	23									AC	10			90
7	1	2	3	19	MA	5			PT	45	LA	45	AC	30			95
71	6	7	4	4	MA	20			DE	10	AG	2	AC	1			5
79	1	3	4	10	PT	50			AL	30	CO	30	BH	2			70

Appendix 3. Density of exposed abalone, by size group, for index sites surveyed in southeast QCI, April 2002.

Site	Number of Quadrats	Total number of Abalone	Exposed Density by Size Group (mm SL) <70	≥70	92-99	100-106	≥100	Total
Cumshewa Inlet								
75	8	0	0.00	0.00	0.00	0.00	0.00	0.00
76	16	0	0.00	0.00	0.00	0.00	0.00	0.00
77	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Selwyn Inlet								
65	8	0	0.00	0.00	0.00	0.00	0.00	0.00
66	8	0	0.00	0.00	0.00	0.00	0.00	0.00
67	16	1	0.06	0.00	0.00	0.00	0.00	0.06
68	16	2	0.13	0.00	0.00	0.00	0.00	0.13
69	16	1	0.00	0.06	0.00	0.00	0.00	0.06
70	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Tanu Island								
59	16	10	0.50	0.13	0.00	0.00	0.00	0.63
60	16	13	0.44	0.38	0.06	0.00	0.00	0.81
61	16	4	0.25	0.00	0.00	0.00	0.00	0.25
62	8	0	0.00	0.00	0.00	0.00	0.00	0.00
63	16	6	0.13	0.25	0.00	0.00	0.00	0.38
64	16	5	0.25	0.06	0.00	0.00	0.00	0.31
73	8	0	0.00	0.00	0.00	0.00	0.00	0.00
74	16	5	0.00	0.31	0.00	0.00	0.13	0.31
Upper Juan Perez Sound								
36	8	0	0.00	0.00	0.00	0.00	0.00	0.00
37	16	14	0.88	0.00	0.00	0.00	0.00	0.88
38	16	4	0.13	0.13	0.06	0.00	0.00	0.25
39	16	6	0.31	0.06	0.00	0.00	0.00	0.38
40	8	0	0.00	0.00	0.00	0.00	0.00	0.00
41	16	3	0.13	0.06	0.00	0.06	0.06	0.19
44	16	2	0.13	0.00	0.00	0.00	0.00	0.13
45	8	0	0.00	0.00	0.00	0.00	0.00	0.00
46	16	24	1.25	0.25	0.00	0.00	0.00	1.50
48	16	4	0.25	0.00	0.00	0.00	0.00	0.25
49	16	4	0.06	0.19	0.06	0.00	0.00	0.25
50	16	4	0.00	0.25	0.06	0.00	0.19	0.25
51	16	7	0.00	0.44	0.06	0.00	0.31	0.44
53	8	0	0.00	0.00	0.00	0.00	0.00	0.00
55	16	5	0.13	0.19	0.00	0.06	0.13	0.31
56	16	6	0.19	0.19	0.00	0.06	0.19	0.38
57	16	1	0.06	0.00	0.00	0.00	0.00	0.06
58	16	9	0.31	0.25	0.00	0.00	0.00	0.56

Appendix 3 (cont'd)

Site	Number of Quadrats	Total number of Abalone	Exposed Density by Size Group (mm SL) <70	≥70	92-99	100-106	≥100	Total
Lower Juan Perez Sound								
42	16	6	0.38	0.00	0.00	0.00	0.00	0.38
43	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Skincuttle Inlet								
22	16	1	0.06	0.00	0.00	0.00	0.00	0.06
23	16	3	0.00	0.19	0.00	0.06	0.19	0.19
24	8	0	0.00	0.00	0.00	0.00	0.00	0.00
26	16	5	0.13	0.19	0.00	0.00	0.00	0.31
27	8	0	0.00	0.00	0.00	0.00	0.00	0.00
28	8	0	0.00	0.00	0.00	0.00	0.00	0.00
29	16	4	0.19	0.06	0.00	0.00	0.00	0.25
30	16	4	0.19	0.06	0.00	0.00	0.00	0.25
31	16	5	0.13	0.19	0.00	0.00	0.06	0.31
32	16	2	0.13	0.00	0.00	0.00	0.00	0.13
33	16	10	0.19	0.44	0.00	0.19	0.25	0.63
34	8	0	0.00	0.00	0.00	0.00	0.00	0.00
35	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Carpenter Bay								
10	8	0	0.00	0.00	0.00	0.00	0.00	0.00
11	16	17	0.38	0.69	0.19	0.00	0.00	1.06
12	16	10	0.06	0.56	0.00	0.06	0.38	0.63
14	16	6	0.31	0.06	0.00	0.00	0.00	0.38
15	16	18	0.56	0.56	0.13	0.00	0.00	1.13
17	8	0	0.00	0.00	0.00	0.00	0.00	0.00
18	16	8	0.00	0.50	0.06	0.06	0.19	0.50
19	16	0	0.00	0.00	0.00	0.00	0.00	0.00
20	16	35	1.94	0.25	0.19	0.00	0.00	2.19
21	8	0	0.00	0.00	0.00	0.00	0.00	0.00
Kunghit Island								
1	16	32	0.38	1.63	0.31	0.19	0.31	2.00
2	16	12	0.38	0.38	0.13	0.00	0.00	0.75
3	16	19	0.50	0.69	0.06	0.25	0.25	1.19
4	16	9	0.38	0.19	0.06	0.06	0.06	0.56
7	16	8	0.31	0.19	0.00	0.06	0.06	0.50
71	16	6	0.06	0.31	0.00	0.00	0.06	0.38
79	16	2	0.00	0.13	0.06	0.06	0.06	0.13

Appendix 4. Total exposed abalone density (number/m^2) and number of quadrats, by site, for all surveyed years. Blanks indicate no samples taken.

	Total abalone density								Total number of quadrats per site							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Cumshewa Inlet																
75	1.13			0.44	0.06	0.00	0.00	0.00	16			16	16	32	16	8
76	2.69	2.19		0.13	0.38	0.19		0.00	16	16		16	16	32		16
77	1.44			0.00		0.06	0.00	0.00	16			4		32	16	8
78	0.88			1.50	0.75	0.06	0.00	0.00	16			16	16	32	16	8
Selwyn Inlet																
65	1.06		0.13	0.50	0.06	0.25	0.31	0.00	16		16	16	16	32	16	8
66	0.63	1.38	0.13	0.31	0.06	0.34	0.88	0.00	16	16	16	16	16	32	16	8
67	0.94		0.00	0.56	0.31	0.09	0.25	0.06	16		8	16	16	32	16	16
68	1.13		0.19	1.19	0.63	0.13	0.50	0.13	16		16	16	16	32	16	16
69	3.88	3.06	0.06	0.19	0.13	0.19	0.00	0.06	16	16	16	16	16	32	16	16
70	3.63	2.13	0.31	0.25	0.06	0.06	0.25	0.00	16	16	16	16	16	32	16	8
Tanu Island																
59	1.44		0.88	1.06	0.63	0.81	0.94	0.63	16		16	16	16	64	16	16
60			1.25	0.63	0.00	0.19	1.38	0.81			16	16	8	64	16	16
61	1.53		0.31	0.00	0.00	0.28	0.13	0.25	32		16	16	8	32	16	16
62			0.56	0.81	0.63	0.16	0.19	0.00			16	16	16	32	16	8
63	1.44		0.19	0.19	0.56	0.31	1.13	0.38	16		16	16	16	32	16	16
64	2.19		0.06	0.75	0.06	0.03	0.38	0.31	16		16	16	16	32	16	16
73				1.00	0.13	0.38	0.06	0.00				16	16	32	16	8
74				0.13	0.06	0.59	0.06	0.31				16	16	32	16	16
Upper Juan Perez Sound																
36	2.44		0.00	0.00	0.00	0.22	0.31	0.00	16		8	16	16	32	16	8
37	1.13		0.00	0.38	0.19	0.06	0.25	0.88	16		8	16	16	32	16	16
38	2.44		1.00	0.69	0.94	0.41	1.00	0.25	16		16	16	16	32	16	16
39	6.38		1.81	0.88	0.31	0.28	0.38	0.38	13		16	16	16	32	16	16
40	1.00		0.13	0.06	0.08	0.03	0.00	0.00	16		16	16	48	32	16	8
41	0.25		0.06	0.06	0.00	0.06	0.13	0.19	16		16	16	16	32	16	16
44	6.56		0.13	0.44	0.06	0.06	0.19	0.13	16		16	16	16	32	16	16
45	4.25		0.75	0.63	0.81	0.13	0.06	0.00	16		16	16	16	32	16	8
46	7.06		0.50	4.00	1.44	0.22	0.38	1.50	16		16	16	16	32	16	16
47			0.00								8					
48	3.63		1.19	0.81	0.44	0.19	0.00	0.25	16		16	16	16	48	16	16
49	1.81		0.56	0.88	2.10	0.25	0.13	0.25	16		16	16	48	64	16	16
50	0.63		1.19	0.38	0.56	0.22	0.06	0.25	16		16	16	16	32	16	16
51	0.75		0.00	0.50	0.38	0.23	0.50	0.44	16		16	16	16	64	16	16
52	8.86		2.00	0.50	0.69	0.06	0.38		7		16	16	16	32	16	
53	8.13		0.31	0.75	0.94	0.00	0.81	0.00	16		16	16	16	32	16	8
54	0.63		1.00	1.50	0.50	0.27			16		16	16	16	64		
55	5.88		0.88	2.56	1.19	0.38	1.00	0.31	16		16	16	16	32	16	16
56	7.25		1.75	1.13	1.75	0.59	0.25	0.38	16		16	16	16	32	16	16
57	2.63		1.00	0.25	0.00	0.00	0.06	0.06	16		16	16	16	32	16	16
58	3.38		0.06	0.25	0.25	0.00	0.38	0.56	16		16	16	16	32	16	16

Appendix 4 (cont'd)

	Total abalone density							Total number of quadrats per site							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Lower Juan Perez Sound																
42	16.56		0.06	1.56	0.63	0.52	0.38	0.38	16		16	16	16	64	16	16
43	9.38		0.31	0.81	0.69	0.27	0.44	0.00	16		16	16	16	64	16	8
Skincuttle Inlet																
22	1.63		0.06	0.00	0.63	0.09	1.06	0.06	16		16	0	16	32	16	16
23	1.13		0.69	0.63	0.31	0.03	0.13	0.19	16		16	16	16	32	16	16
24	0.75		0.81	1.13	0.38	0.25	0.13	0.00	16		16	16	16	48	16	8
25	2.25		0.75						16		16					
26	0.56		2.00	2.13	1.25	0.34	0.56	0.31	16		16	16	16	32	16	16
27	0.63		0.00	0.06	0.06	0.06		0.00	16		8	16	16	32		8
28	3.06		1.13	1.13	0.31	0.88	0.25	0.00	16		16	16	16	32	16	8
29	0.94		0.69	0.38	0.19	0.34	0.38	0.25	16		16	16	16	32	16	16
30	3.31		1.25	0.44	0.88	0.53	0.69	0.25	16		16	16	16	32	16	16
31	1.75		0.50	0.94	0.25	0.31	0.13	0.31	16		16	16	16	32	16	16
32	5.75		0.00	0.50	0.13	0.09	0.00	0.13	16		8	16	16	32	16	16
33	3.00		0.81	0.75	0.06	1.16	1.00	0.63	16		16	16	16	32	16	16
34	6.13		0.94	0.44	0.19	0.25	0.94	0.00	16		16	16	16	28	16	8
35	0.31		0.38	0.50	0.06	0.34	0.25	0.00	16		16	16	16	32	16	8
72				1.00								16				
Carpenter Bay																
10	1.06		0.69	0.56	0.31	0.34	0.50	0.00	16		16	16	16	32	16	8
11	0.19		0.00	0.19	0.06	0.16	1.06	1.06	16		8	16	16	32	16	16
12	0.13		0.19	0.19	0.31	0.22	0.88	0.63	16		16	16	16	32	16	16
13	2.47		0.42						15		12					
14	2.31		0.56	0.63	1.56	0.31	0.38	0.38	16		16	16	16	32	16	16
15	3.38		0.50	0.44	0.38	0.97	3.00	1.13	16		16	16	16	32	16	16
16	2.56		0.06						16		16					
17	1.19		0.06	0.56	0.13	0.41	0.63	0.00	16		16	16	16	32	16	8
18	1.44		0.81	0.25	0.25	0.63	0.31	0.50	16		16	16	16	32	16	16
19	1.00		0.00	0.38	0.31	0.91	0.50	0.00	16		16	16	16	32	16	16
20	1.13		1.63	0.07	0.31	0.72	2.50	2.44	16		16	15	16	32	16	16
21	0.94		0.00	0.00	0.00	0.03	0.44	0.00	16		8	8	8	32	16	8
Kunghit Island																
1		1.56	1.06	1.06	1.94	0.47	0.31	2.00	16	16	16	16	16	32	16	16
2		2.38	0.44	1.06	1.50	0.22	0.94	0.75	16	16	16	16	16	32	16	16
3		0.75	0.38	0.38	0.94	1.63	0.88	1.19	16	8	16	16	16	32		16
4			0.13	0.44	0.13	0.00		0.56			16	16	16	32		
5			0.00								8					
6			0.50	0.00							16	8				
7			0.19	0.13	0.19	0.16	0.13	0.50			16	16	16	32	16	16
8			0.06								16					
9			0.44								16					
71				0.31	0.19	0.19	0.69	0.38				16	16	32	16	16
79					0.31	0.03	0.31	0.13				16	32	16	16	

Appendix 5. Abalone densities (number/m^2) for legal and mature size classes, by site, for all sample years. Blanks indicate no samples taken. Index sites only.

	Legal (≥ 100 mm SL) abalone density								Mature (≥ 70 mm SL) abalone density							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Cumshewa Inlet																
75	0.84			0.44	0.06	0.00	0.00	0.00	1.05			0.44	0.06	0.00	0.00	0.00
76	0.08			0.06	0.13			0.00	0.96			0.13	0.25			0.00
77	0.44			0.00		0.06	0.00	0.00	0.81			0.00		0.06	0.00	0.00
78	0.75			1.50	0.69	0.03	0.00	0.00	0.88			1.50	0.69	0.06	0.00	0.00
Selwyn Inlet																
65	0.05		0.00	0.13	0.00	0.06	0.00	0.00		0.75	0.06	0.44	0.06	0.09	0.06	0.00
66	0.31	0.38	0.06	0.13	0.00	0.03	0.00	0.00			0.13	0.25	0.06	0.17	0.25	0.00
67	0.14		0.00	0.19	0.06	0.00	0.00	0.00			0.00	0.44	0.06	0.00	0.13	0.00
68	0.40		0.00	0.25	0.25	0.00	0.00	0.00	0.99		0.00	0.63	0.38	0.03	0.00	0.00
69	0.39	0.20	0.00	0.06	0.00	0.06	0.00	0.00		2.06	0.00	0.13	0.06	0.19	0.00	0.06
70	0.54	0.39	0.05	0.00	0.06	0.03	0.00	0.00		1.74	0.16	0.00	0.06	0.03	0.06	0.00
Tanu Island																
59	0.36		0.13	0.69	0.25	0.29	0.38	0.00			0.75	1.00	0.50	0.63	0.88	0.13
60			0.36	0.49	0.00	0.14	0.69	0.00			1.25	0.63	0.00	0.16	1.25	0.38
61	0.40		0.19	0.00	0.00	0.00	0.00	0.00	1.43		0.25	0.00	0.00	0.06	0.06	0.00
62			0.25	0.25	0.13	0.03	0.06	0.00			0.56	0.44	0.38	0.09	0.13	0.00
63	0.21		0.00	0.00	0.00	0.00	0.07	0.00	0.68		0.00	0.09	0.44	0.24	0.73	0.25
64	1.42		0.00	0.44	0.06	0.00	0.25	0.00	2.12		0.06	0.71	0.06	0.03	0.38	0.06
73				0.94	0.13	0.25	0.00	0.00				1.00	0.13	0.34	0.06	0.00
74				0.13	0.06	0.16	0.06	0.13				0.13	0.06	0.22	0.06	0.31
Upper Juan Perez Sound																
36	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.13		0.00	0.00	0.00	0.00	0.00	0.00
37	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.21	0.00	0.03	0.00	0.00
38	0.24		0.00	0.06	0.25	0.10	0.13	0.00			0.44	0.44	0.75	0.20	0.47	0.13
39	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.38		0.13	0.00	0.19	0.07	0.19	0.06
40	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
41	0.00		0.06	0.00	0.00	0.06	0.00	0.06			0.06	0.06	0.00	0.06	0.06	0.06
44	0.06		0.00	0.13	0.00	0.00	0.00	0.00	3.13		0.06	0.31	0.00	0.03	0.13	0.00
45	0.13		0.19	0.06	0.25	0.00	0.00	0.00	1.55		0.31	0.31	0.50	0.06	0.06	0.00
46	0.00		0.00	0.00	0.00	0.00	0.00	0.00	1.67		0.06	0.31	0.00	0.03	0.00	0.25
47			0.00								0.00					
48	0.54		0.38	0.13	0.06	0.13	0.00	0.00	1.63		0.94	0.38	0.25	0.15	0.00	0.00
49	1.63		0.42	0.70	0.33	0.14	0.00	0.00			0.49	0.82	1.71	0.23	0.00	0.19
50	0.56		0.75	0.31	0.44	0.09	0.00	0.19			1.13	0.38	0.56	0.22	0.00	0.25
51	0.68		0.00	0.44	0.31	0.23	0.38	0.31			0.00	0.50	0.38	0.23	0.50	0.44
52	0.00		0.00	0.00	0.00	0.00	0.00		0.00		0.00	0.00	0.00	0.06	0.00	
53	1.22		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
54	0.00		0.08	0.41	0.19	0.08			0.25		0.77	1.16	0.44	0.20		
55	3.53		0.06	0.26	0.56	0.09	0.25	0.13			0.56	2.18	0.88	0.34	0.81	0.19
56	0.36		0.13	0.50	0.44	0.09	0.06	0.19			1.19	1.00	1.25	0.47	0.25	0.19
57	0.13		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
58	0.12		0.00	0.00	0.00	0.00	0.00	0.00	1.66		0.00	0.08	0.00	0.00	0.25	0.25

Appendix 5 (cont'd)

	Legal (≥ 100 mm SL) abalone density								Mature (≥ 70 mm SL) abalone density							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Lower Juan Perez Sound																
42	1.25		0.00	0.13	0.06	0.02	0.00	0.00	11.52		0.00	0.69	0.19	0.03	0.06	0.00
43	0.47		0.00	0.00	0.00	0.00	0.00	0.00			0.19	0.06	0.13	0.02	0.00	0.00
Skincuttle Inlet																
22	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.03	0.06	0.00
23	0.11		0.28	0.21	0.13	0.03	0.06	0.19			0.69	0.63	0.31	0.03	0.13	0.19
24	0.40		0.07	0.19	0.00	0.04	0.00	0.00	0.75		0.68	1.00	0.38	0.25	0.06	0.00
25	0.11		0.29								0.52					
26	0.51		0.45	0.86	0.25	0.00	0.25	0.00	0.56		1.81	2.06	1.00	0.25	0.50	0.19
27	0.16		0.00	0.06	0.06	0.03		0.00	0.42		0.00	0.06	0.06	0.06		0.00
28	0.07		0.00	0.00	0.00	0.00	0.00	0.00	0.27		0.00	0.06	0.00	0.06	0.00	0.00
29	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.06	0.06	0.03	0.06	0.06
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.13	0.00	0.06
31	0.09		0.28	0.69	0.06	0.19	0.00	0.06			0.50	0.88	0.19	0.22	0.06	0.19
32	0.45		0.00	0.00	0.00	0.00	0.00	0.00	4.28		0.00	0.13	0.06	0.00	0.00	0.00
33	1.10		0.31	0.38	0.00	0.59	0.50	0.25	2.51		0.75	0.63	0.06	1.03	0.94	0.44
34	0.26		0.19	0.06	0.00	0.00	0.00	0.00	1.74		0.81	0.31	0.06	0.18	0.69	0.00
35	0.03		0.31	0.13	0.00	0.19	0.19	0.00			0.38	0.50	0.00	0.31	0.25	0.00
72				0.88								1.00				
Carpenter Bay																
10	0.06		0.06	0.28	0.19	0.31	0.44	0.00	0.69		0.52	0.51	0.31	0.34	0.44	0.00
11	0.06		0.00	0.00	0.00	0.03	0.00	0.00	0.19		0.00	0.13	0.06	0.16	0.50	0.69
12	0.10		0.06	0.09	0.06	0.00	0.81	0.38			0.19	0.19	0.31	0.13	0.88	0.56
13	0.00		0.00						0.33		0.00					
14	0.93		0.06	0.00	0.00	0.00	0.00	0.00			0.44	0.19	0.81	0.28	0.00	0.06
15	0.13		0.00	0.00	0.00	0.00	0.00	0.00	2.04		0.19	0.06	0.06	0.53	1.44	0.56
16	0.20		0.00						1.31		0.00					
17	0.06		0.00	0.00	0.00	0.00	0.13	0.00			0.06	0.21	0.00	0.28	0.44	0.00
18	0.44		0.38	0.04	0.06	0.20	0.25	0.19	1.19		0.81	0.21	0.19	0.36	0.31	0.50
19	0.00		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.06	0.06	0.22	0.06	0.00
20	0.00		0.00	0.00	0.00	0.06	0.13	0.00	0.50		0.75	0.07	0.25	0.44	1.13	0.28
21	0.19		0.00	0.00	0.00	0.03	0.00	0.00			0.00	0.00	0.00	0.03	0.00	0.00
Kunghit Island																
1		0.30	0.12	0.19	0.38	0.13	0.00	0.31		1.02	1.00	0.75	1.63	0.34	0.06	1.63
2		0.96	0.13	0.11	0.31	0.00	0.00	0.00		2.12	0.44	0.84	0.69	0.00	0.67	0.38
3		0.43	0.21	0.05	0.13	0.16	0.13	0.25		0.64	0.38	0.27	0.81	1.27	0.56	0.69
4			0.00	0.15	0.00	0.00		0.06			0.00	0.29	0.00	0.00		0.19
5			0.00								0.00					
6			0.07	0.00							0.21	0.00				
7			0.06	0.00	0.06	0.06	0.13	0.06			0.13	0.00	0.19	0.16	0.13	0.19
8			0.00								0.06					
9			0.06								0.31					
71				0.31	0.13	0.13	0.50	0.06				0.31	0.19	0.19	0.69	0.31
79					0.13	0.00	0.00	0.06					0.25	0.03	0.25	0.13

Appendix 6. Abalone densities (number/m^2) for pre-recruit and new recruit size classes, by site, for all sample years. Blanks indicate no samples taken. Index sites only.

	Pre-recruit (92-99 mm SL) abalone density								New Recruit (100-106 mm SL) abalone density							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Cumshewa Inlet																
75	0.07			0.00	0.00	0.00	0.00	0.00	0.14			0.00	0.00	0.00	0.00	0.00
76	0.12			0.00	0.06			0.00	0.00			0.00	0.06			0.00
77	0.13			0.00		0.00	0.00	0.00	0.06			0.00		0.00	0.00	0.00
78	0.13			0.00	0.00	0.03	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00
Selwyn Inlet																
65			0.00	0.13	0.06	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
66		0.13	0.06	0.06	0.00	0.00	0.06	0.00		0.25	0.00	0.00	0.00	0.03	0.00	0.00
67			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.13	0.06	0.00	0.00	0.00
68	0.13		0.00	0.13	0.00	0.00	0.00	0.00	0.13		0.00	0.13	0.06	0.00	0.00	0.00
69		0.40	0.00	0.00	0.00	0.00	0.00	0.00		0.13	0.00	0.06	0.00	0.00	0.00	0.00
70		0.64	0.00	0.00	0.00	0.00	0.00	0.00		0.32	0.05	0.00	0.06	0.00	0.00	0.00
Tanu Island																
59			0.25	0.19	0.06	0.11	0.13	0.00			0.00	0.50	0.06	0.07	0.19	0.00
60			0.30	0.07	0.00	0.00	0.25	0.06			0.06	0.07	0.00	0.00	0.13	0.00
61	0.37		0.00	0.00	0.00	0.03	0.00	0.00	0.17		0.06	0.00	0.00	0.00	0.00	0.00
62			0.13	0.00	0.19	0.00	0.00	0.00			0.00	0.06	0.00	0.03	0.00	0.00
63	0.07		0.00	0.00	0.00	0.07	0.07	0.00	0.21		0.00	0.00	0.00	0.00	0.07	0.00
64	0.39		0.00	0.09	0.00	0.03	0.00	0.00	0.39		0.00	0.09	0.00	0.00	0.06	0.00
73				0.06	0.00	0.03	0.06	0.00				0.18	0.06	0.00	0.00	0.00
74				0.00	0.00	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.00
Upper Juan Perez Sound																
36	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
37			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
38			0.00	0.06	0.13	0.03	0.00	0.06			0.00	0.00	0.13	0.00	0.00	0.00
39	0.00		0.00	0.00	0.00	0.00	0.06	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
40			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
41			0.00	0.00	0.00	0.00	0.06	0.00			0.00	0.00	0.00	0.06	0.00	0.06
44	0.31		0.00	0.13	0.00	0.00	0.00	0.00	0.06		0.00	0.06	0.00	0.00	0.00	0.00
45	0.19		0.06	0.06	0.06	0.00	0.00	0.00	0.00		0.19	0.00	0.19	0.00	0.00	0.00
46	0.38		0.06	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00
47			0.00								0.00					
48	0.24		0.31	0.00	0.00	0.02	0.00	0.00	0.24		0.13	0.06	0.00	0.04	0.00	0.00
49			0.07	0.00	0.31	0.06	0.00	0.06			0.14	0.17	0.17	0.05	0.00	0.00
50			0.19	0.06	0.06	0.03	0.00	0.06			0.13	0.06	0.00	0.06	0.00	0.00
51			0.00	0.06	0.06	0.00	0.06	0.06			0.00	0.06	0.00	0.02	0.19	0.00
52	0.00		0.00	0.00	0.00	0.00	0.00		0.00		0.00	0.00	0.00	0.00	0.00	
53			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
54	0.00		0.08	0.27	0.00	0.02			0.00		0.00	0.14	0.13	0.02		
55			0.06	0.45	0.19	0.06	0.06	0.00			0.00	0.19	0.31	0.06	0.19	0.06
56			0.13	0.13	0.38	0.06	0.06	0.00			0.00	0.25	0.19	0.09	0.00	0.06
57			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
58	0.47		0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00

Appendix 6 (cont'd)

	Pre-recruit (92-99 mm SL) abalone density								New Recruit (100-106 mm SL) abalone density							
Site	1978	1979	1984	1987	1990	1994	1998	2002	1978	1979	1984	1987	1990	1994	1998	2002
Lower Juan Perez Sound																
42	2.49		0.00	0.06	0.13	0.00	0.06	0.00	0.93		0.00	0.13	0.00	0.02	0.00	0.00
43			0.06	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Skincuttle Inlet																
22			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
23			0.34	0.21	0.06	0.00	0.00	0.00			0.07	0.07	0.00	0.00	0.00	0.06
24	0.00		0.07	0.13	0.00	0.06	0.00	0.00	0.23		0.07	0.06	0.00	0.02	0.00	0.00
25			0.00								0.12					
26	0.00		0.65	0.66	0.25	0.09	0.06	0.00	0.11		0.26	0.20	0.13	0.00	0.06	0.00
27	0.16		0.00	0.00	0.00	0.03		0.00	0.05		0.00	0.00	0.00	0.03		0.00
28	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.07		0.00	0.00	0.00	0.00	0.00	0.00
29			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
30			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
31			0.22	0.13	0.00	0.00	0.00	0.00			0.11	0.25	0.06	0.03	0.00	0.00
32	0.89		0.00	0.00	0.00	0.00	0.00	0.00	0.19		0.00	0.00	0.00	0.00	0.00	0.00
33	0.31		0.19	0.13	0.00	0.19	0.38	0.00	0.55		0.06	0.25	0.00	0.22	0.25	0.19
34	0.19		0.06	0.06	0.00	0.00	0.06	0.00	0.06		0.19	0.06	0.00	0.00	0.00	0.00
35			0.00	0.19	0.00	0.03	0.00	0.00			0.06	0.06	0.00	0.03	0.00	0.00
72				0.06								0.06				
Carpenter Bay																
10	0.06		0.06	0.11	0.00	0.03	0.00	0.00	0.00		0.00	0.06	0.13	0.03	0.00	0.00
11	0.06		0.00	0.00	0.00	0.00	0.06	0.19	0.06		0.00	0.00	0.00	0.03	0.00	0.00
12			0.06	0.00	0.00	0.03	0.00	0.00			0.06	0.00	0.06	0.00	0.13	0.06
13	0.07		0.00						0.00		0.00					
14			0.19	0.00	0.00	0.03	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
15	0.32		0.06	0.00	0.00	0.06	0.31	0.13	0.13		0.00	0.00	0.00	0.00	0.00	0.00
16	0.39		0.00						0.20		0.00					
17			0.00	0.00	0.00	0.06	0.13	0.00			0.00	0.00	0.00	0.00	0.06	0.00
18	0.19		0.00	0.00	0.00	0.03	0.00	0.06	0.19		0.06	0.00	0.06	0.07	0.06	0.06
19			0.00	0.00	0.06	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
20	0.06		0.19	0.00	0.06	0.16	0.00	0.21	0.00		0.00	0.00	0.00	0.03	0.13	0.00
21			0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	0.00	0.03	0.00	0.00
Kunghit Island																
1		0.18	0.24	0.06	0.50	0.06	0.00	0.31		0.24	0.00	0.19	0.31	0.06	0.00	0.19
2		0.32	0.06	0.22	0.13	0.00	0.13	0.13		0.51	0.00	0.06	0.31	0.00	0.00	0.00
3		0.11	0.11	0.00	0.50	0.35	0.06	0.06		0.32	0.11	0.05	0.13	0.13	0.06	0.25
4			0.00	0.00	0.00	0.00		0.06			0.00	0.15	0.00	0.00		0.06
5			0.00								0.00					
6			0.00	0.00							0.07	0.00				
7			0.06	0.00	0.00	0.03	0.00	0.00			0.00	0.00	0.00	0.00	0.06	0.06
8			0.06								0.00					
9			0.13								0.06					
71				0.00	0.00	0.03	0.13	0.00				0.00	0.00	0.00	0.25	0.00
79					0.00	0.00	0.06	0.06					0.13	0.00	0.00	0.06

Appendix 7. Additional sites from 1978 and 1979, not included Appendix 4-6 as index sites.

Year-Site	# of Quadrats	Abalone counted	All sizes	Immature	Mature	Pre-recruit	New Recruit	Legal
78-1	16	11	0.69					0.52
78-2	16	17	1.06					0.53
78-4	16	10	0.63					0.47
78-10	16	46	2.88	0.72	2.16	0.13	0.39	1.44
78-11	8	0	0.00					0.00
78-16	16	16	1.00	0.24	0.76	0.47	0.12	0.18
78-17	16	7	0.58	0.07	0.51	0.15	0.07	0.29
78-18	16	22	1.38	0.48	0.89	0.14	0.00	0.21
78-20	8	1	0.13					0.00
78-21	16	43	2.69	0.69	2.00	0.50	0.19	0.56
78-22	16	11	0.69					0.00
78-23	16	52	3.25					1.63
78-26	16	12	0.75					0.52
78-27	16	8	0.50					0.35
78-28	16	25	1.56	0.75	0.81	0.19	0.06	0.19
78-29	16	20	1.25	0.59	0.66	0.20	0.07	0.07
78-35	16	31	1.94					1.74
78-36	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78-39	16	9	0.56					0.42
78-42	16	42	2.63	1.83	0.79	0.06	0.00	0.00
78-43	16	11	0.69					0.00
78-44	16	26	1.63					1.22
78-45	16	74	4.63					0.23
78-46	16	29	1.81					0.73
78-47	16	11	0.69					0.00
78-48	16	74	4.63					0.93
78-49	12	3	0.25					0.00
78-52	16	29	1.81	1.81	0.00	0.00	0.00	0.00
78-54	16	38	2.38					0.00
78-58	16	16	1.00	0.95	0.05	0.00	0.00	0.00
78-60	16	55	3.44					0.34
78-61	16	118	7.38	5.41	1.96	0.47	0.14	0.20
78-63	16	15	0.94	0.11	0.83	0.17	0.33	0.55
78-66	16	47	2.94	0.47	2.47	0.53	0.00	0.33
78-77	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78-86	16	4	0.25					0.19
78-87	16	48	3.00	0.70	2.30	0.38	0.32	0.32
78-90	16	29	1.81					1.09
78-92	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78-93	16	24	1.50					0.38
78-101	8	1	0.13					0.13
78-110	16	3	0.19					0.00
78-116	16	2	0.13					0.00
78-117	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78-120	8	0	0.00	0.00	0.00	0.00	0.00	0.00
78-129	16	3	0.19					0.00
79-58	16	65	4.06	0.57	3.49	0.57	0.63	1.90
79-60	16	2	0.13					0.00
79-63	16	93	5.81	2.31	3.50	0.56	0.25	0.38